THE B-1B BOMBER AND OPTIONS FOR ENHANCEMENTS

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NOTE

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PREFACE

The B-1B bomber has many special features that enhance its ability to penetrate Soviet air defenses. Even so, many reported deficiencies--including shortcomings in the bomber's defensive and offensive avionics and a range that is shorter than anticipated--have instilled doubts about its capability to perform the mission for which it was originally designed. These reports have raised three fundamental questions:

- How serious are the deficiencies?
- Should the United States change current plans and use the B-1B as a standoff bomber carrying cruise missiles rather than as a penetrating bomber?
- What enhancements should the Congress fund to improve the B-1B as either a penetrating bomber or as a standoff bomber?

This study by the Congressional Budget Office (CBO), performed at the request of the House Committee on Armed Services, addresses the first two issues and then examines several options for enhancing the B-1B bomber. In keeping with CBO's mandate to provide objective analysis, the study does not recommend any particular course of action.

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SUMMARY

The United States is modernizing each leg of its "triad" of strategic nuclear weapons, which includes land-based intercontinental ballistic missiles, sea-launched missiles, and bombers. Bombers are being modernized in several ways. The United States is developing the new B-2 or "stealth" bomber, which incorporates features that hide it from enemy radar. Older B-52G and B-52H bombers are being modified to carry air-launched cruise missiles--small, pilotless drones that can be launched at long distances from a target. Two new weapons for bombers are also being developed: an advanced cruise missile for long-range attacks and a new short-range attack missile.

In addition to modernizing existing aircraft, the United States has just completed deployment of 100 new B-1B bombers that are the focus of this analysis. Those bombers have experienced a variety of problems that diminish their performance. The Air Force is striving to solve those problems. Moreover, it will probably propose a package of enhancements to expand the B-1B's capabilities. If all enhancements currently under consideration are pursued, that package could cost as much as $8 billion.

This study first reviews the status of the Air Force programs to correct the problems with the B-1B and then reviews the choices the Congress could make regarding the anticipated enhancements. Those choices depend in large part on the mission selected for the B-1B bomber. Should it be employed as long as possible in a role that requires it to penetrate Soviet airspace to attack targets at short ranges? Or should it be transferred to a standoff role, employing cruise missiles to attack targets at longer ranges?

THE B-1B BOMBER

The B-1 bomber was developed as a high-speed aircraft designed to penetrate Soviet airspace, evading Soviet air defense radars by flying low to the ground. The Carter Administration canceled the first version of the B-1, now referred to as the B-1A, however, arguing that employing B-52s as standoff bombers would maintain the effectiveness of the air-based leg of the strategic triad at lower cost. The Carter Administration also had begun development of the stealthy B-2 bomber for the role of penetrating enemy airspace.

The Reagan Administration disagreed and resurrected the B-1, partially redesigning the aircraft and naming it the B-1B. Under the Administration's "two-bomber" plan, the B-1B aircraft is intended to serve as a penetrating bomber until the B-2 bomber is deployed in the 1990s. At that time, the B-1B would be used for "shoot-and-penetrate" missions, launching externally carried cruise missiles before penetrating Soviet defenses and attacking targets with bombs and short-range missiles. The first squadron of 15 B-1B bombers became operational in October 1986, and subsequent deliveries were on or ahead of schedule. The one-hundredth B-1B was delivered to the Air Force on April 30, 1988.

The costs of deploying the B-1B have remained relatively close to original estimates. The "baseline" costs of the B-1B bomber will be close to the ceiling of $20.5 billion (in 1981 dollars) established by the Congress. Baseline costs exclude some items that are necessary for deploying the B-1B, including certain physical facilities and flight simulators. B-1B costs in these nonbaseline categories have exceeded the original estimates. Nonetheless, including all costs, the B-1B program will probably be no more than 14 percent above estimates presented by the Administration in 1981.

PROBLEMS THAT LIMIT THE B-1B's PERFORMANCE

Since the B-1B became operational, many problems have surfaced that might diminish its performance as a penetrating bomber. Four of these reported problems are serious, while the others are relatively minor. The Air Force has already solved some of these problems and anticipates finding and carrying out remedies for most of the rest by 1992. But the most serious problem--deficiencies in the defensive avionics system--is not likely to be solved by 1992, leaving in doubt the time when the B-1B will meet all its original design specifications.

Major Problems

The more serious problems involve deficiencies in the B-1B's defensive and offensive avionics; in its payload capacity during low-altitude, terrain-following flights; and in its logistical support.

Shortcomings in Defensive Avionics. Redesign of the defensive avionics to protect the B-1B from Soviet air defenses is the most important and potentially most expensive problem faced by the Air Force. The Air Force had initiated a three-phase plan designed to bring the defensive avionics system on all B-1B bombers up to the design specifications by 1992.

In recent tests of the second phase of that plan, however, the Air Force found that the system's basic architecture--the way the system processes enemy radar signals--is deficient. Although the system can identify and counter the "top 10" airborne threats in a low-threat environment, it would be overwhelmed in a high-threat environment and would be unable to use appropriate electronic countermeasures against Soviet defenses.

The Air Force is now evaluating this problem in detail, and a report is expected in October 1988. It is now unlikely that the Air Force will meet its previous goal of bringing the defensive avionics system on all B-1Bs up to the design specifications by 1992. Also, the cost of reaching those design specifications may rise, potentially causing the baseline costs of the B-1B to exceed the Congressional ceiling of $20.5 billion.

Small Payload Capacity. The B-1B cannot fly at as high an angle of attack (angle between the wing and relative air flow) as anticipated, reducing the bomber's payload (fuel and munitions) during low-altitude, terrain-following flight to about 125,000 pounds, which is significantly less than planned. This smaller payload reduces the amount of fuel the B-1B can carry, limiting its range at low altitudes to about 1,300 miles, which is insufficient for many strategic missions.

To improve the B-1B's payload capacity and therefore its range, the Air Force is modifying the B-1B's basic flight control system to enable the bomber to fly at higher angles of attack. One modification, the Stall Inhibitor System (SIS), will improve the B-1B's payload capacity by about 30,000 pounds, increasing the low-altitude, terrain-following range of the B-1B to roughly 1,800 miles. The Air Force hopes that a second modification, the Stability Enhancement Function (SEF), will enable the B-1B to carry an additional 80,000 pounds, which could increase the B-1B's terrain-following range to more than 3,000 miles.

The Air Force completed installation of SIS on the first group of B-1Bs (bombers numbered 2 through 18) in June 1988 and is scheduled to complete installation on the remainder by June 1990. Installation of SEF is scheduled for completion by January 1992.

Offensive Avionics: High Rate of Unnecessary Flyups. The automatic terrain-following (ATF) system has caused a high rate of unnecessary "flyups," incidents in which the B-1B pitches up rapidly because it senses obstacles that do not exist or reports suspected malfunctions during a self-check. The Air Force is solving this problem, which wastes fuel and exposes the bomber to enemy air defenses, by revising software that controls the system. Although recent test-flight data indicate that problems remain, revised software should enable the Air Force to reach its goal of an average of 15 minutes between flyups under all types of conditions such as terrain, weather, altitude, speed, and so on.

Shortcomings in Logistical Support. The supply of trained flight crews and the provision of spare parts have been the main logistical challenges. The Air Force is rapidly resolving the first problem; it has reached the goal of one flight crew per primary authorized aircraft and expects to certify all crews in low-altitude flight by November 1988. The provision of spares is more complex. More spare parts are being delivered, but the number of flight hours--and therefore the demand for spare parts--has grown as more planes are delivered and more crews are trained. It is not yet possible to determine whether these factors will increase or decrease the shortage of spare parts in the near term, but the problem will eventually be resolved if spare parts are adequately financed.

Minor Problems

The B-1B has suffered many other minor problems. The Air Force has largely resolved several of these problems including fuel leaks, interference between the offensive and defensive avionics, inadequate performance of the on-board Central Integrated Test System, and problems with the release of weapons from the bomb bays. Also, although some questions have been raised about the ability of the B-1B to carry cruise missiles externally, there does not appear to be a significant problem. Two other reported problems--that the bomber is overweight and unable to fly at required altitudes--are based on misconceptions.

THE STRENGTH OF SOVIET AIR DEFENSES AND THE ROLE OF THE B-1B

A sophisticated weapons system like the B-1B bomber is never really complete. Even as the Air Force seeks to correct problems in the original B-1B design, the service is considering enhancements to improve the bomber's capability. Though not yet formally presented to the Congress, some of these enhancements are likely to be proposed in the Administration's defense budget for fiscal year 1990.

The desirability of many of these enhancements depends on the B-1B's future mission. Should the bomber continue as long as possible to penetrate Soviet air defenses? Or should it move to a standoff role, in which it launches long-range cruise missiles at targets while flying outside Soviet defenses?

These questions require analysis of two issues: How difficult is it to penetrate Soviet air defenses? What are the relative merits of a penetrating bomber compared with those of a standoff bomber?

The Strength of Soviet Air Defenses

Estimates of the B-1B's ability to penetrate Soviet air defenses in a retaliatory strike are affected by many factors, including:

- The circumstances (Did the Soviet attack follow a crisis or come out of the blue?);

- The number of U.S. ballistic missile warheads dedicated to suppressing Soviet air defenses;

- The effect of high-altitude electromagnetic pulse on Soviet military electronics, and the impact of U.S. ballistic missile warheads on the Soviet command system;

- U.S. tactics (such as using air-launched cruise missiles carried by B-52s to suppress defenses and using fighters to attack Soviet aircraft that carry tracking radars) and Soviet tactics (such as the number of fighters dedicated to intercepting U.S. bombers);

- The choice of targets, which may or may not be defended; and

- The effectiveness of particular Soviet defensive systems and of the B-1B's countermeasures.

There are reasonable arguments for selecting different assumptions in regard to these factors. Thus, one could construct scenarios in which the B-1B currently penetrates Soviet air defenses easily and would continue to do so through the 1990s. One could also construct scenarios in which the bomber currently suffers a high rate of attrition and performs even worse as better Soviet defenses are deployed.

The Air Force evaluated the factors noted above in 1981 and concluded that the B-1Bs would, with an acceptable rate of attrition, be able to penetrate heavily defended areas well into the 1990s. This judgment, however, was based on the B-1B's having a defensive avionics system that meets the baseline requirements. If the Air Force is unable to meet those requirements, that judgment might be unjustified.

Merits of Penetrating and Standoff Bombers

Advocates of penetrating and standoff bombers have different perspectives on the relative merits of penetrating and standoff tactics.

Advantages of Penetrating Bombers. Proponents of penetrating bombers claim that such bombers have many potential advantages over bombers that stand off and launch cruise missiles. One advantage, they argue, is that, because a penetrating bomber can carry a larger warhead and deliver it accurately, the bomber is more effective against Soviet targets that are heavily hardened against nuclear attacks--such as silos for intercontinental ballistic missiles (ICBMs) and command centers. A bomber also can conduct a "damage assessment/strike" mission, flying close to a potential target to determine if it was destroyed by a previous warhead and, if it was not, to attack it.

Proponents further contend that the penetrating bomber is the best platform for attacking targets that can move about, such as mobile ICBMs. Bombers have both the sensors for finding mobile targets and the weapons to destroy them; the pilot can use human judgment to select the best targets and tactics.

Moreover, a penetrating bomber can penetrate terminal defenses more effectively than cruise missiles. Whereas cruise missiles approach a target slowly, a bomber launches short-range missiles that approach the target at a high speed and angle, making them much harder to shoot down. It also can deliver conventional munitions to support the United States in conflicts around the world.

Penetrating bombers may also offer advantages in ongoing arms control negotiations. Under counting rules for limiting warheads, which have reportedly been accepted by both the United States and the Soviet Union, the United States could deploy more nuclear warheads if it deploys penetrating bombers than if it deploys standoff bombers. Each bomber carrying bombs and short-range attack missiles would be counted as only one warhead; each bomber carrying cruise missiles would be counted as carrying a higher number of warheads yet to be negotiated.

Advantages of Standoff Bombers. Proponents of standoff bombers challenge many of these arguments for penetrating bombers and note additional advantages for standoff bombers equipped with cruise missiles. They say that the arguments in favor of penetrating bombers are flawed for a number of reasons:

- Penetrating bombers may not be the best weapon for destroying Soviet targets, such as command centers and ICBM silos, that are hardened against nuclear attacks. Ballistic missile warheads, which arrive quickly and minimize the chance these facilities will be used to attack the United States, may be more effective.

- Penetrating bombers may not be the best choice for the damage assessment/strike mission, since flying over a facility might expose the bomber to Soviet air defenses. A better approach would be to target the facility with a second warhead carried by either a ballistic missile or a cruise missile, leaving the bomber free for other tasks.

- The United States does not currently have the sensors necessary to find Soviet mobile missiles. When such sensors become available, a low-flying bomber like the B-1B might not be the preferred platform for the mission since it would have to fly higher to use them, exposing itself to Soviet air defenses.

- Even if they are not designed to penetrate enemy defenses, standoff bombers can be useful in conventional conflicts by using conventional standoff weapons.

- The United States should not agree to an arms control treaty that favors penetrating bombers over cruise missiles if the bombers are not the most cost-effective method of attacking Soviet systems.

Advocates also claim that standoff bombers equipped with cruise missiles have advantages over penetrating bombers. Like penetrating bombers, air-launched cruise missiles exploit weaknesses in Soviet air defenses by flying low. But the missiles have a smaller radar cross section, making it more difficult for Soviet radars to find them.

Moreover, a standoff bomber launching cruise missiles (one B-1B can carry up to 20 cruise missiles) overwhelms air defenses with superior numbers. Cruise missiles also are very flexible. They could be operated as decoys, equipped with defensive avionics, or equipped with sensors for the damage assessment/strike mission or missions against mobile targets.

Standoff bombers may hold down the costs of the U.S. bomber fleet. Pursing only a standoff capability in the future would save money by enabling the United States to cancel both the SRAM II and the B-2 stealth bomber.

As with the issue of the B-1B's ability to penetrate Soviet defenses, this study cannot reach a final conclusion about the desirability of a penetrating bomber compared with a standoff bomber. But there are questions about the merits of both types of bombers that the Congress should consider while assessing which, if any, enhancements to approve for the B-1B.

ENHANCEMENTS FOR THE B-1B BOMBER

The Air Force is considering enhancements that relate to offensive avionics, defensive avionics, command and control, weapons integration, and supporting systems. These enhancements can be split into four functional groups. One group would improve supporting systems that would enhance the B-1B as both a standoff bomber that carries cruise missiles and as a penetrating bomber. The second group would complete preparations for the B-1B to carry cruise missiles on either shoot-and-penetrate missions or standoff missions. The third and fourth groups would enhance the B-1B as a penetrating bomber: the third would improve survivability, and the fourth would improve flexibility.

Of course, the Congress need not approve any enhancements to the B-1B bomber, leaving it with the baseline cost and capability discussed above. But, if history is a guide, enhancements to the capability of a major weapons system will be seriously considered.

Option 1: Improve Basic Support Systems

This option would fund six enhancements that improve systems that support the B-1B as either a standoff or a penetrating bomber. These enhancements would improve the B-1B's navigation and communication capability, further "harden" the aircraft against high-altitude nuclear blasts, redesign some components to increase their reliability, and make other modifications (see the Summary Table).

The costs of this option would be about $1.2 billion over the next five years and $1.7 billion in total. (Costs for this and subsequent options are based on preliminary Air Force estimates.)

The enhancements in this option contribute to the B-1B's capability whether it operates as a penetrating bomber, shoot-and-penetrate bomber, or standoff bomber. Thus, the enhancements are not related to the debate concerning the B-1B's future role and would be consistent with implementing any of the other options discussed below. In addition, several of the enhancements raise little controversy. After acquiring the B-1B, maintaining its resistance to the effects of high-altitude nuclear blasts seems sensible; and given the billions of dollars being spent to deploy the NAVSTAR navigation satellites and MILSTAR communication satellites, it also makes sense to enable the B-1B to use the capabilities they provide.

Option 2: Improve the B-1B's Capability to Carry Cruise Missiles

Since the capability to carry cruise missiles was incorporated into the design of the B-1B, few enhancements are required to enable most B-1Bs to operate as shoot-and-penetrate bombers or standoff bombers. The two enhancements included in this option are described in the Summary Table. Indeed, this is the least expensive option, costing only about $90 million.

Selection of this option probably would not end the B-1B's role as a penetrating bomber. The Air Force still anticipates solving the problems in the B-1B's defensive avionics and has estimated that the B-1B, in its baseline configuration, would be an effective penetrator well into the 1990s and possibly longer. This option would therefore be compatible with the Administration's current "two-bomber" plan, in which the B-1B would be maintained as a penetrator until the B-2 is deployed. It would also be compatible with an alternative approach in which the United States does not procure the new B-2 penetrating bomber and instead uses the B-1B as a standoff bomber to maintain the effectiveness of the bomber leg of the strategic triad.

This option is also compatible with use of the B-1B in a conventional conflict. The B-1B probably would not be used to fly over well-defended targets and drop conventional munitions, given the high risk that the bomber would be shot down. More likely, it would be equipped with standoff conventional munitions for which the baseline B-1B would be an effective platform.

For proponents of penetrating bombers, however, this option has a major disadvantage: if the B-2 is not deployed, or if its deployment is delayed significantly because of budgetary limits or technical problems, the United States could find itself without an effective penetrating bomber at some future date. In that case, the country would forfeit the advantages of penetrating bombers noted by their proponents.

Option 3: Improve the B-1B's Survivability as a Penetrating Bomber

This option would fund seven improvements designed to enhance the B-1B's capability to penetrate Soviet air defenses by better enabling the bomber to destroy or outwit those defenses. These enhancements include the integration of the new short-range attack missile (SRAM II) and improved electronics for jamming or deceiving enemy radars (see the Summary Table).

The major advantage of this option is that it would extend the period during which the B-1B would be an effective penetrator of Soviet air defenses. This should ensure that the United States would continue to have an effective penetrator until the B-2 is developed and deployed, even if technical problems delay its deployment. Opponents of the B-2 might also favor this option because it may make postponement or cancellation of the B-2 more reasonable. When the enhanced B-1B penetrating bomber becomes susceptible to Soviet air defenses at some future date, the alternatives of procuring a new bomber--the B-2 or some yet-to-be designed aircraft--or of switching to dependence on a standoff bomber could be debated anew.

SUMMARY TABLE. DESCRIPTION AND COST OF ENHANCEMENT PROGRAMS FOR THE B-1B BOMBER (Costs in millions of current dollars)

Enhancement Program	Description	1990-1994	Cost to Complete	Total Cost
	Option 1: Improve Basic Support Systems			
Second Inertial Navigation System	Provides a second INS to back up the first, which establishes the B-1B's position by measuring its movements from a reference point	30	0	30
Global Positioning System Receivers	Integrates receivers for GPS, a satellite system that enables the B-1B to determine its precise location	50	10	60
MILSTAR Communications Satellite System	Integrates terminals for MILSTAR, a satellite system designed for communication during a nuclear war	170	20	190
Reliability and Maintainability	Redesigns parts to improve their reliability	590	0	590
Hardness Against Nuclear Blast	Tests and designs parts to maintain their resistance to nuclear effects such as electromagnetic pulse	30	0	30
Interface for External Weapons	Installs wiring for carrying advanced munitions on the B-1B's external pylons	300	490	790
Total		1,170	520	1,690
	Option 2: Improve the B-1B's Capability to Carry Cruise Missiles			
Cruise Missile Capability	Equips seven B-1B bombers, which were not equipped during production, to carry cruise missiles	60	0	60
External Observable Differences	Develops and installs EODs, modifications that would distinguish B-1Bs equipped to carry cruise missiles from those that are not so equipped	30	0	30
Total		90	0	90

SOURCE: Compiled by the Congressional Budget Office from data supplied by the U.S. Air Force.

SUMMARY TABLE. Continued

Enhancement Program	Description	1990-1994	Cost to Complete	Total Cost
Option 3: Improve the B-1B's Survivability as a Penetrating Bomber				
Integration of SRAM II	Wires bomb bays for the #1760 weapon interface required for control of the SRAM II short-range attack missile	610	0	610
Monopulse Countermeasure	Improves ability to jam or confuse monopulse radars on Soviet fighters	540	900	1,440
Forward Warning System	Detects air-to-air missiles approaching the bomber from the front	270	390	660
Improved #1122 Countermeasure	Improves this classified system for countering Soviet air-to-air missiles	60	0	60
Research and Development Assets	Purchases parts of defensive avionics system for use in developmental testing at laboratories	170	0	170
Operation of Anechoic Chamber	Operates an anechoic chamber to test the B-1B's defensive avionics system	70	0	70
General Avionics Enhancements	Improves data storage and displays for terrain-following system and assessment of defensive threats	360	0	360
Total		2,080	1,290	3,370
Option 4: Improve the B-1B's Flexibility as a Penetrating Bomber				
Improved Synthetic Aperture Radar	Improves resolution of ground-mapping capability	620	20	640
High-Resolution Infrared Sensor for Targeting	Provides high-resolution infrared images to enhance targeting of mobile missiles	390	620	1,010
On-Board Mission Planning System	Provides computer and data facilities for planning and evaluating changes in the B-1B's basic mission	500	90	590
Low-Resolution Infrared Sensor for Situational Awareness	Provides infrared images of surrounding terrain, enhancing low-altitude or nighttime navigation	370	130	500
Total		1,880	860	2,740

This option would cost substantially more than Options 1 and 2--about $2.1 billion over the next five years, with a total cost of $3.4 billion. Yet it is not clear that this investment is necessary to maintain the B-1B as a penetrating bomber, since the baseline B-1B is expected to be effective in that role--assuming remedies can be found for the shortcomings in its defensive avionics--at least through the mid-1990s. Moreover, in the opinion of proponents of standoff bombers, this option would spend money without achieving any significant capability not currently possessed by standoff bombers equipped with cruise missiles. As noted above, proponents argue that existing bombers equipped with cruise missiles challenge Soviet air defenses better than a penetrating bomber like the B-1B, with or without enhancements.

Option 4: Improve the B-1B's Flexibility as a Penetrating Bomber

This option would fund four modifications that would improve the B-1B's flexibility during a penetrating mission. The enhancements would improve the B-1B's ability to search for mobile targets, to navigate during low-altitude, terrain-following flight, and to plan changes during a mission (see the Summary Table).

Based on preliminary estimates, this option would cost about $1.9 billion over the next five years and $2.7 billion in total. Choosing this option would be consistent with also implementing Option 1 (improve basic support systems) and Option 3 (improve the B-1B's survivability) to maximize the B-1B's capability as a penetrating bomber. The cost for the three options together would be about $5.1 billion over five years and $7.8 billion in total.

By improving sensors and autonomous mission-planning capability, these enhancements might improve the B-1B's ability to find and destroy mobile targets such as mobile Soviet ICBMs. The better sensors might also improve the B-1B's ability to conduct damage assessment/strike missions and, potentially, conventional missions.

From another viewpoint, however, even with the improved sensors, the B-1B falls short of having the capability to find and attack mobile targets effectively. Among other factors, the B-1B would not have the range to search a large area and, in flying higher to try to search, would expose itself to Soviet air defenses. Moreover, it is not evident that these additional enhancements would significantly improve the B-1B's ability to perform its primary penetrating mission against fixed targets.

CHAPTER I

INTRODUCTION

The United States has several types of strategic nuclear weapons with which it can attack a potential enemy from great distances. The traditional "triad" of strategic weapons comprises sea-based ballistic missiles, land-based ballistic missiles, and long-range bombers.

Many strategic programs are under way that will greatly expand the capability and flexibility of this triad. For the sea-based leg, the United States is procuring the more accurate and powerful Trident II submarine-launched ballistic missiles (SLBMs) for initial deployment on Trident submarines in 1990 and is deploying nuclear sea-launched cruise missiles, which can be launched from either submarines or surface ships. To modernize the land-based leg, the United States is completing deployment of 50 ten-warhead MX intercontinental ballistic missiles (ICBMs) in concrete silos. In addition, the United States is considering the deployment of two mobile ICBM systems. If the programs are funded, a small single-warhead ICBM would be deployed on specially configured trucks, and the ten-warhead MX ICBM would be deployed on railroad cars. Finally, the United States is upgrading the bomber leg of the triad by equipping some B-52 bombers with cruise missiles, fielding the B-1B bomber, developing the B-2 "stealth" bomber, and developing improved weapons--the advanced cruise missile and a new short-range attack missile, the SRAM II.

This study focuses on one element of these modernization programs--enhancements to the newly deployed B-1B bomber.[1] The focus has been chosen to address in detail questions regarding reported deficiencies in the B-1B's capabilities and the issue of whether the B-1B should be employed in the future as a penetrating bomber or as a standoff bomber that carries cruise missiles.

1. For an overview of basic options for each leg of the strategic triad, see Congressional Budget Office, *Modernizing U.S. Strategic Offensive Forces: Costs, Effects, and Alternatives* (November 1987).

EVOLUTION OF THE STRATEGIC NUCLEAR BOMBER

In the beginning of the nuclear age, the bomber was the sole means of delivering a nuclear weapon to a distant target. On August 6, 1945, the Enola Gay, a U.S. B-29 bomber, dropped a nuclear bomb on the Japanese city of Hiroshima. The United States dropped a second bomb on Nagasaki a few days later.

Bombers continued to be the primary means for delivering nuclear weapons until deployment of intercontinental ballistic missiles began in 1958. Ballistic missiles are rockets that shoot into space and release warheads that fall back to earth to attack their intended targets. These missiles had three basic advantages: they could be based far from the potential battle site, enhancing survivability; the warheads, which approached their targets from space, were immune to existing enemy defenses; and the short time in which the missiles could reach an enemy target (about 30 minutes for ICBMs and less for SLBMs) increased the probability of destroying the enemy's forces before the enemy could use them to respond.

These basic advantages have given ballistic missiles a major role in U.S. strategic forces. Even so, bombers have features that have continued to make them an important part of the triad. Because of their diverse basing and operating characteristics, many technological advances that might enhance the enemy's ability to attack U.S. ICBMs or SLBMs would not enhance the enemy's ability to attack bombers, strengthening confidence in the survivability of nuclear forces as a whole. Furthermore, U.S. officials can enhance the ability of bombers to survive an attack by dispersing them to a greater number of bases, employing higher levels of strip alert (bombers parked on the runway ready to take off), or placing the bombers on airborne alert. The U.S. President can employ this flexibility during a crisis to signal growing concern to a potential adversary. Unlike ballistic missiles, bombers can be recalled, and their slow speed reduces their ability to destroy an enemy's forces in a first strike, potentially enhancing crisis stability.

The main concern about U.S. strategic bombers, however, is that Soviet air defenses--which include anti-aircraft guns, surface-to-air missiles (SAMs), and interceptors (fighter aircraft assigned to attack the bombers) equipped with air-to-air missiles--would become sophisticated enough to shoot them down. This concern has prompted five major developments in the design and tactics of U.S. bombers.

- o Because the greater range and accuracy of modern air defense systems have made them very effective against bombers flying at high altitudes, current penetrating bombers have been designed for low-altitude flight. By flying 200 to 400 feet above the ground, a bomber can enhance its survivability by using the curvature of the earth to hide from ground-based radars.

- o A penetrating bomber now carries, in addition to bombs, short-range attack missiles (SRAMs) that it can use to attack a target from a distance. This enhances a bomber's survivability when attacking defended targets by eliminating the need to fly over them. The SRAM-A currently carried by U.S. bombers enables them to attack a target from a range of about 40 to 80 miles.

- o As an alternative to low-altitude penetration and SRAMs, a bomber can "stand off"--that is, stay outside a nation's air defenses--and fire air-launched cruise missiles (ALCMs). The ALCMs are small, pilotless, jet-powered planes. They fly to their targets using inertial guidance and terrain contour matching, which compares preprogrammed contour map data with measurements of the terrain below to calculate necessary course corrections.

- o A bomber can use sophisticated defensive technology to defend itself, including electronic countermeasures, decoys, flares (burning projectiles that draw heat-seeking missiles away from the bomber), and chaff (zinc-coated glass fibers that reflect radar signals, thus confusing radar-guided missiles).

- o Many "stealth" technologies are being developed to decrease the amount of radar energy that a bomber reflects, decreasing the range at which an enemy radar can detect it. These technologies, some of which were used on the B-1B, are being applied extensively on the "stealth" bomber currently under development.

ORIGINS OF THE B-1 BOMBER

The first U.S. bomber to incorporate many of these features was the B-52, a large "heavy" bomber built between 1954 and 1962 to replace the B-36. During its service, the B-52 has been equipped with air-to-surface missiles, improved electronic countermeasures, and decoys. The B-52G, for example, was equipped at one time with the Hound Dog air-to-surface missile, which had a range of over 500 miles. It was also equipped with the Quail air decoy, which flew at about the same speed and altitude as the B-52 and created a similar radar image.

Although the B-52 was built as a high-altitude bomber, the Air Force modified many B-52s to serve as low-altitude bombers, maximizing survivability against Soviet air defenses. These modifications included new offensive avionics, updated defensive avionics, and SRAM-A missiles. The SRAMs were intended for destroying targets as well as for destroying air defenses while en route to targets. Also, many B-52 bombers have been modified to carry cruise missiles.

In the 1960s, the Air Force began to consider building a new heavy bomber to replace the B-52. The Air Force produced about 100 supersonic bombers named the B-58, but they proved unsatisfactory and were retired by 1970. The service developed a prototype of the XB-70 in 1964, which was designed to fly three times the speed of sound and operate at 75,000 feet, but canceled it shortly thereafter because of doubts that it would be able to fly high enough to be out of range of Soviet surface-to-air missiles and because it did not compare favorably with the speed and survivability of ICBMs.

The Air Force also procured 76 smaller FB-111 "medium" bombers based on the F-111 airframe. These aircraft are effective penetrators because of their small size, high speed, and ability to fly close to the ground. They have, however, a shorter range and smaller payload than heavy bombers like the B-52. The FB-111's unrefueled range is about 3,000 nautical miles (nm) compared with about 6,000 nm for the B-52 (precise ranges depend on altitude, speed, payload, and weather). The maximum load (including external munitions) for the FB-111 is six nuclear weapons; the B-52G and B-52H can carry 24.

Following development of the XB-70, the search for a new heavy bomber continued under the Advanced Manned Strategic Aircraft program. That program led to contracts for the development of a new bomber in 1970. The design of the bomber emphasized the capability to fly at low altitudes to minimize exposure to Soviet air defenses. The new bomber would fly lower and faster than the modified low-altitude B-52s and would have a smaller radar cross section.[2] In addition, it would have more advanced offensive avionics for identifying targets and more advanced defensive avionics for outwitting defenses that it could not avoid or destroy.

The new penetrating bomber was named the B-1. Development continued from 1970 through the mid-1970s, but the B-1 was expensive, fueling a debate over whether money was better invested in a new penetrating bomber like the B-1 or in a standoff bomber that would rely on cruise missiles to destroy enemy targets. In June 1977, the Carter Administration canceled the B-1, deciding that a better option was to modify B-52s to carry cruise missiles and continue development of a new bomber incorporating "stealth" technology for avoiding detection by enemy radars.

TWO-BOMBER PROGRAM

Ronald Reagan campaigned for the presidency in 1980 on a platform that included resurrecting the B-1 bomber. The Congress supported this objective indirectly by funding the Long-Range Combat Aircraft program in the fiscal year 1981 Defense Authorization Act. This program was dedicated to deployment of a new bomber by 1987.

As required by this act, the Defense Department studied several options for a new strategic bomber, including the B-1, a stretched version of the FB-111, and the "stealth" bomber started by the Carter Administration. In October 1981, President Reagan recommended developing and procuring not one, but two of these bombers. Under this "two-bomber" program, the Administration would develop a modified B-1 (the modified plane was named the B-1B to distinguish it from the original B-1, now designated the B-1A) as the Long-Range Combat

2. The radar cross section is a measurement of the amount of radar energy reflected by a plane. The smaller a plane's radar cross section, the closer it can fly to enemy radars before being detected.

Aircraft. The Administration also recommended proceeding with development of the "stealth" bomber, which was referred to as the Advanced Technology Bomber and is now designated the B-2.

Under this program, the B-52G would be equipped with cruise missiles. The B-52H would continue as a penetrating bomber until the B-1B was deployed in 1986 to 1988, at which time the B-52H would be equipped with cruise missiles. Then, when the B-2 was deployed as a penetrating bomber some time in the 1990s, the B-1B would be transferred to a "shoot-and-penetrate" role, launching cruise missiles from outside Soviet air defenses and then penetrating with bombs and SRAMs.

The B-1B differed from the B-1A in that it was designed to fly at subsonic rather than supersonic speeds when penetrating Soviet territory and to carry ALCMs as well as bombs and SRAMs. The Air Force determined that supersonic penetration speed and the resulting reduction in time the B-1B would be exposed to enemy radar was not worth the low fuel efficiency incurred at that speed. Also, because the B-1B would be superseded as a penetrator by the B-2 under the two-bomber program, it made sense to include the capability to carry cruise missiles in the initial B-1B design.

In addition, the frontal radar cross section of the B-1B was reduced tenfold over that of the B-1A, primarily by putting baffles in front of the jet air intakes and using more composite materials in constructing the airframe.[3] The schedule for the B-1B called for initial operational capability--defined as the deployment of one operational squadron of 15 planes--by October 1986.

Few details are known about the B-2 bomber because it has remained a "black" program in which the engineering design and planned capabilities are highly classified. The objective, however, is to make it difficult for Soviet radars or infrared sensors to detect the bomber in time to attack it. Techniques to minimize the B-2's radar cross section reportedly include extensive use of composite materials

3. The frontal radar cross section measures the radar energy reflected if the radar is directly in front of the plane. Many analysts contend, however, that the amount of radar energy reflected when the radar is in other positions vis-a-vis the bomber is also important in evaluating a bomber's ability to penetrate. No unclassified estimates are available for the B-1B's radar cross section from these other aspects.

and surface coatings that absorb radar energy, and rounded surfaces that disperse radar energy in many directions.[4]

The Reagan Administration also supported the development of two new weapons for bombers: the advanced cruise missile (ACM) and the SRAM II. The ACM is an air-launched cruise missile that will feature a greater range than the currently deployed ALCM-B and stealth technology to make it less detectable by radar. Initial deployment might be delayed to the early 1990s by production problems. The SRAM II is being developed as a replacement for the currently deployed SRAM-A. It will have greater range, reliability, accuracy, and flexibility. Initial procurement of the SRAM II is scheduled for 1990, with initial deployment in 1993.

STATUS OF THE B-1B PROGRAM

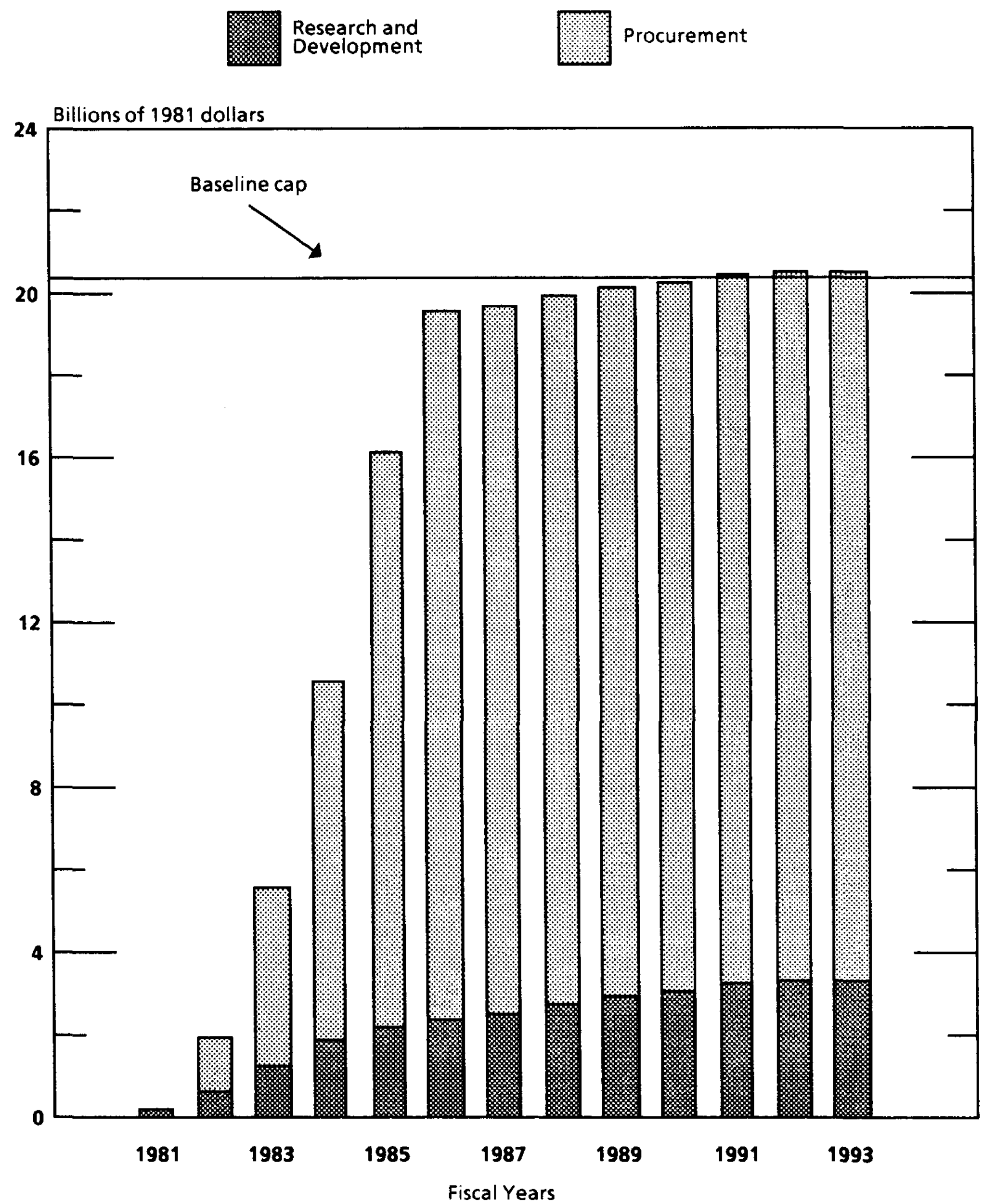
The Congress supported all the basic elements of the two-bomber program outlined by the Reagan Administration in 1981, including the plan to deploy the B-1B by 1986. The Congress demanded, however, a commitment to limiting the basic costs for developing and deploying the B-1B to $20.5 billion (in constant 1981 dollars), which was in addition to several billion dollars that had been spent on developing the B-1 before 1981.

Delivery of the first squadron of B-1B bombers was completed on schedule in October 1986. Subsequent deliveries also occurred on or ahead of schedule, and it now appears that the total cost of the baseline program, as defined by the Air Force, will be close to the cap of $20.5 billion (see Figure 1).[5] However, the price of other "nonbase-

4. For an extensive discussion of stealth technology, see Bill Sweetman, *Stealth Aircraft: Secrets of Future Airpower* (Osceola, Wisc.: Motorbooks International Publishers, 1986).

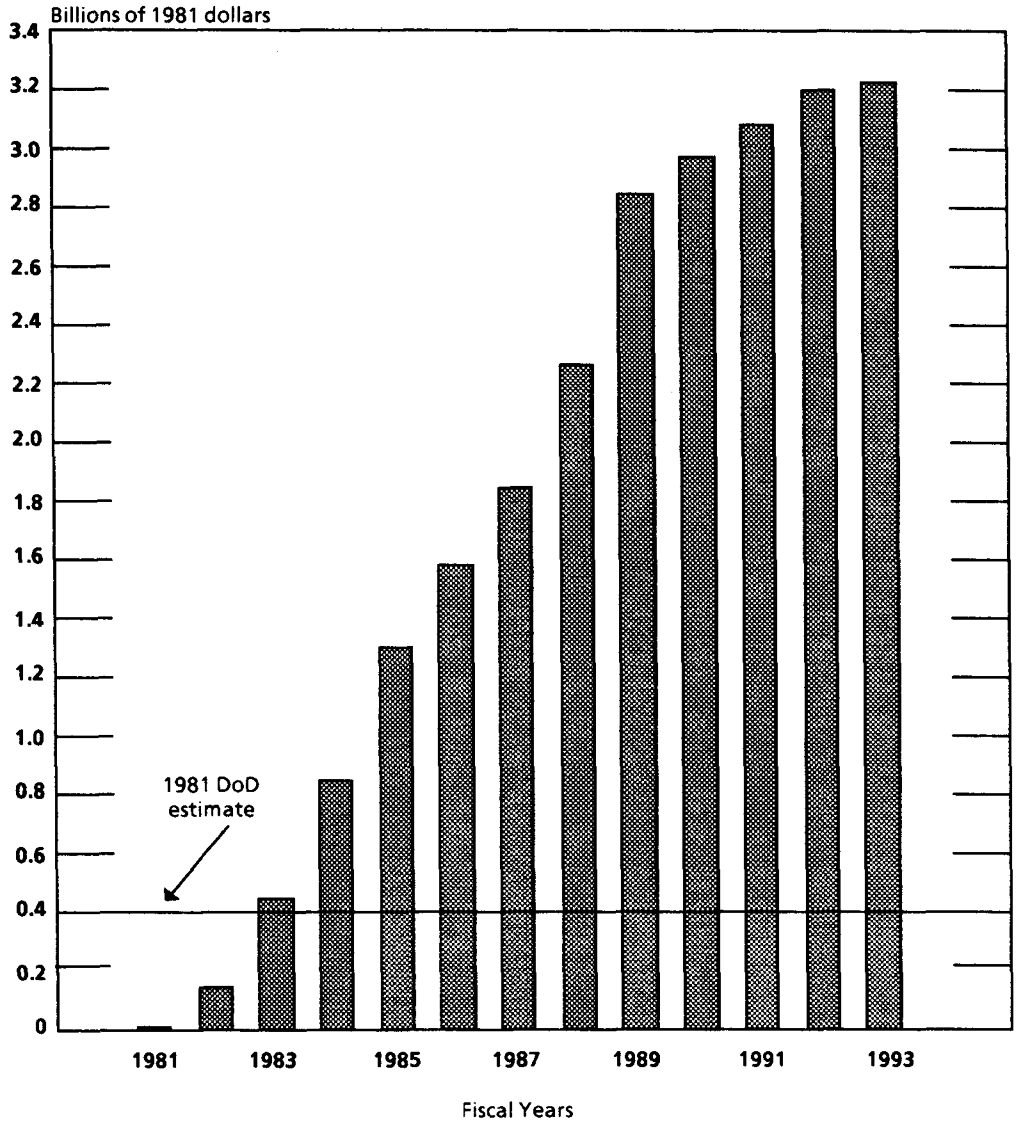
5. Because solutions to several major problems must still be designed, tested, and produced, it is not possible currently to determine whether total baseline costs will be slightly below or above the cost cap. In any event, the significance of the cost cap should not be overstated. Many gray areas exist between the defined baseline and other funding categories pertaining to deployment of the B-1B, including the development of some B-1B components, operation and maintenance of the bomber, enhancements to the bomber, and certain "nonbaseline" costs. The baseline cost cap could be met by shifting some costs into these other categories.

Figure 1.
Cumulative B-1B Baseline Costs, 1981-1993



SOURCE: Congressional Budget Office analysis of data provided by the General Accounting Office. See GAO, *Strategic Bombers: Estimated Costs to Deploy the B-1B* (GAO/NSIAD-88-12, October 1987).

Figure 2.
Cumulative B-1B Nonbaseline Costs, 1981-1993



SOURCE: Congressional Budget Office analysis of data provided by the General Accounting Office. See GAO, *Strategic Bombers: Estimated Costs to Deploy the B-1B*, (GAO/NSIAD-88-12, October 1987). The Department of Defense's 1981 estimate is from *Strategic Force Modernization Programs*, Hearings before the Subcommittee on Strategic and Theater Nuclear Forces of the Senate Committee on Armed Services, 97:1 (1981), p. 110.

line" components of the program necessary for deploying the B-1B bombers has risen. The cost of these nonbaseline components--which include flight simulators, necessary facilities, parts, and support equipment--grew from initial Defense Department estimates of between $300 million and $400 million to about $3.3 billion in 1981 dollars (see Figure 2 on previous page).[6] Overall, therefore, the costs of procuring the B-1B bomber increased about 14 percent following agreement to the cost cap in 1981.

FUTURE ISSUES FOR THE B-1B PROGRAM

Although the B-1B was delivered on schedule and with relatively modest cost increases, its deployment has been controversial because of reports claiming it has a number of problems, such as fuel leaks and inadequate defensive avionics, that reduce its effectiveness as a penetrating bomber. These reports have raised several issues, including:

- How serious are the deficiencies?
- Can they be fixed at a reasonable cost?
- Should the B-1B, as a result of these deficiencies, be employed as a standoff bomber rather than as a penetrating bomber?

While working to fix problems with the existing B-1B, the Air Force is also considering enhancements to the aircraft. The enhancements, which informal estimates suggest could cost as much as $8 billion, have not yet been proposed to the Congress but may well be part of the budget proposal for fiscal year 1990. That raises the issue of whether the Congress should begin to fund enhancements to the B-1B and whether such enhancements should be aimed at performing a penetrating or a standoff mission. This report addresses these issues.

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6. For the Defense Department's original estimates of the costs of nonbaseline components, see *Strategic Force Modernization Programs*, Hearings before the Subcommittee on Strategic and Theater Nuclear Forces of the Senate Committee on Armed Services, 97:1 (1981), p. 110.

   For the current costs of nonbaseline components, see General Accounting Office, *Strategic Bombers: Estimated Costs to Deploy the B-1B* (GAO/NSIAD-88-12, October 1987).

CHAPTER II

WORKING THE "BUGS" OUT

The B-1B has many special features. Its wings sweep back for fast flight close to the ground and sweep forward to increase lift for slower flight or flight at higher altitudes. A small frontal radar cross section enhances its ability to penetrate Soviet air defenses.

In addition, the B-1B has three weapon bays, each of which can carry either eight nuclear bombs, eight nuclear short-range attack missiles, 28 conventional bombs, or a fuel tank. The bulkhead between the front and middle bays can be moved forward, creating a longer bay that can accommodate eight cruise missiles and a shorter bay that can hold a small fuel tank. Each plane can also carry 12 cruise missiles externally.[1]

Despite these special features, deployment of the bomber has been controversial because of reports of deficiencies that diminish its capability. This chapter describes many of those conditions, grouping them into major and minor categories. The chapter also notes the degree to which the problems affect the bomber's performance and reviews the progress the Air Force is making in resolving them.

MAJOR PROBLEMS

Major systems of a bomber include the airframe, the propulsion system, the flight control system, the offensive avionics, and the defensive avionics. On the B-1B bomber, there are no major problems with the airframe or the propulsion system. Several major problems,

1. This is a change from the original plan in which the B-1B would carry 14 cruise missiles externally. Carrying only 12 missiles externally, in addition to eight internally, limits the total number of cruise missiles the B- 1B can carry to 20. That is the number of ALCMs that the B-1 was permitted to carry under the SALT II treaty. Also, this change might strengthen U.S. efforts at the START negotiations to credit the B-1B, when carrying cruise missiles, with fewer warheads under a ceiling on strategic warheads.

however, have been reported in other systems. The most important problem is a deficiency in the defensive avionics. Other major problems include a small payload capacity during low-altitude, terrain-following flight; a high rate of unnecessary "flyups" by the automatic terrain-following system; and shortcomings in logistical support for the aircraft.

Deficiencies in the Defensive Avionics System

The B-1B's defensive avionics system has deficiencies that limit its capability to detect and defeat Soviet air defenses. These defenses include perimeter defenses that employ ground-based, surface-to-air missiles (SAMs) and fighter aircraft with air-to-air missiles. In addition, when arriving near a target, a bomber could be attacked by terminal defenses that might include SAMs, air-to-air missiles, and anti-aircraft guns. To penetrate these defenses, bombers follow a three-step strategy: (1) avoid the threat; (2) outwit the threat; (3) destroy the threat.

A bomber's defensive avionics system--electronic hardware and software dedicated to defending the bomber--has a role in each of these steps. One function of the defensive avionics is to locate and identify threats based on their radar emissions. This function alerts the bomber crew so that it can choose whether to avoid a potential threat by changing course or to protect the bomber by pursuing steps two or three of the defensive strategy.

In step two, the crew would use the B1-B's defensive avionics system to attempt to outwit the threat by transmitting signals designed either to jam or to deceive enemy airborne and ground-based radars. In step three, the crew could use a bomber's tail warning function, a radar that searches for missiles approaching the rear of the bomber, to detect such missiles and activate last-ditch electronic countermeasures and physical countermeasures such as the ejection of flares and chaff. Also, the crew could use short-range, air-to-surface missiles to destroy threats such as ground-based radars.[2]

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2. Currently, the air-to-surface missiles carried by bombers on strategic missions are all armed with nuclear warheads. Thus, the crew is unlikely to employ the missiles against targets that are not designated in advance since the nuclear detonation could interfere with the flight plan assigned to other bombers, disrupting a carefully coordinated attack.

Status of the B-1B's Defensive Avionics. Design and production of the B-1B's defensive avionics system, named the ALQ-161, posed one of the most challenging hurdles to deploying the B-1B by 1986. The ALQ-161 required major advances beyond work performed under the B-1A program. In an attempt to complete the system in time for deployment with the first squadron of B-1B bombers, the Air Force developed and produced it concurrently.

This plan failed. Numerous development problems blocked completion of the ALQ-161 system in time for deployment in 1986. As a result, the defensive avionics system installed on each lot of B-1B bombers reflected work to date on an evolving design. By the time B-1B production was completed, many different versions of the defensive avionics system had been produced and deployed, but all fell short of the original specifications. Although the ALQ-161 had some capability to identify the source and location of threats, there were major problems in its active electronic countermeasures and tail warning function.

Consequently, although the bomber can avoid some threats, it is poorly prepared to outwit threats or to destroy attacking missiles. This deficiency will be increasingly important as the Soviet Union deploys more aircraft dedicated to tracking and more fighters equipped with "look-down" radars (see Chapter III).

To remedy this deficiency, the Air Force planned a new engineering program to equip all B-1B bombers by 1992 with a modified ALQ-161 defensive avionics system that meets the original B-1B specifications. This program was organized into three phases labeled Mod 0, Mod 1, and Mod 2.

Mod 0 consisted of modifying the defensive avionics system on each bomber so that the B-1B bombers would have identical systems, facilitating the introduction of Mod 1 and Mod 2. Mod 1 would then modify the ALQ-161 to provide several features including selected automatic (versus manual) jamming and operation of the tail warning function. Mod 1 involved some hardware changes, but this phase focused on developing a new version of the defensive avionics software titled "block 4.0." Additional software and hardware changes would then be made in Mod 2 to bring the ALQ-161 up to the original B-1B specifications. Installation of Mod 2 was to start in 1989 and be completed on all B-1Bs by 1992.

Installation of Mod 0 was completed on most B-1Bs in 1987. The Air Force chose not to install Mod 0 on 18 B-1Bs to save costs, planning to go directly to Mod 2 when it became available.

The Air Force proceeded to flight-test Mod 1 in March through June 1988. The tests revealed that the defensive avionics had good capabilities to identify and counter the "top 10" airborne threats--that is, the airborne threats thought to present the greatest challenge to the B-1B's survival on a strategic mission.

The tests also demonstrated, however, that Mod 1 cannot process a large number of radar signals simultaneously as required in the B-1B specifications. Thus, the defensive avionics could be overwhelmed in a a high-threat environment, preventing the B-1B from using appropriate electronic countermeasures against Soviet air defenses. The Air Force has concluded that this serious deficiency is caused by the ALQ-161's basic architecture--the way it processes signals on the eight radar bands it covers.

A New Air Force Plan. The Air Force is therefore now rethinking its plan for the B-1B's defensive avionics and has reached three basic conclusions. First, the software version 4.0 developed under Mod 1 can make a limited improvement in the performance of the ALQ-161 and therefore should be deployed on the B-1B bombers.

Second, the Air Force has concluded that software modifications alone cannot overcome the serious deficiency in the ALQ-161's architecture. The Air Force has put Mod 2 on hold and has assigned its Systems Command and Strategic Air Command to study alternative architectures and to present options by October 1988. By changing the architecture so that the ALQ-161 would process signals in only a few radar bands, for example, the Air Force might be able to salvage the capability of the current defensive avionics against the most important air defense threats while keeping the system from being overloaded in a high-threat environment. Also, since Mod 2 is on hold, the B-1B Program Office is preparing a plan to install Mod 0 on the 18 aircraft previously exempted.

Third, the Air Force must begin to consider long-term options for improving the B-1B's defensive avionics, since even the revised ALQ-161 might not meet all the original B-1B specifications--which were based on the air defense threats of the 1980s--let alone the threats of the 1990s. Long-term options might include adding various enhancements already under study (see Chapter IV).

The recent conclusion that the architecture of the ALQ-161 has a serious deficiency leaves in doubt the schedule, cost, and performance of improvements in the B-1B's defensive avionics, at least until the Air Force completes its current review. The B-1B's defensive avionics will probably not achieve the level of performance called for in original specifications for the baseline B-1B bomber in the near term, and may never achieve that level without major modification.

Small Payload Capacity During Terrain-following Flight

The B-1B is designed to fly at low elevations of 200 to 400 feet during a penetrating mission in order to avoid Soviet air defenses. During such terrain-following flights, the B-1B must have the ability to maneuver, including the ability to pull up sharply to avoid hitting hills. To maintain the ability to pull up at the level desired by the Air Force (2.4 g's, or gravitational equivalents, for 10 seconds), however, the B-1B can only carry about 125,000 pounds of munitions and fuel, which is significantly less than originally planned. This situation has occurred because the B-1B cannot, with its basic flight control system, fly at as high an angle of attack (the angle between the wing and the relative air flow) as anticipated, reducing the amount of weight it can carry.

For any given load of munitions, this reduced payload capacity restricts the amount of fuel the B-1B can carry, which in turn limits its range. With a load of eight SRAM-As and eight B61 bombs, for example, the B-1B has a low-altitude, terrain-following range of just over 1,300 miles (see Appendix A for the methodology used in calculating payload capacity and range).[3]

3. The Air Force has determined that the B-1B meets its specifications for a low-altitude, terrain-following flight of 1,726 miles (1,500 nautical miles). The B-1B can meet this specification, however, only if the bomber's low-altitude flight is straight and level so that the bomber does not need to maneuver. Under these assumptions, the bomber can fly at a heavier weight and increase its range by carrying more fuel.

This low-altitude, terrain-following range is insufficient for many penetrating missions. For example, during a mission in which a B-1B starts flying at a low altitude 300 miles from the coast of the Soviet Union (to escape radar detection), enters the Soviet Union near Murmansk (the northwestern corner of the Soviet Union), attacks targets near Moscow, and continues flying at a low altitude until it reaches the border of the Soviet Union en route to a recovery base in Italy, the B-1B's low-altitude flight would be about 2,000 miles.

Several tactical measures can be taken to extend the B-1B's range, but all have potential drawbacks related to weapon payload, safety, or exposure to Soviet air defenses. One method would be to have the B-1B carry fewer weapons and more fuel. By carrying only four SRAM-As, for example, rather than eight SRAM-As and eight bombs, the B-1B could carry enough extra fuel to fly roughly 300 miles farther. Another method would be to have the B-1B begin its terrain-following flight when closer to the intended target, but this would increase the risk of being detected and attacked by Soviet air defenses. Alternatively, the B-1B could save fuel by flying more slowly during part of its low-altitude mission, but doing so would expose the bomber to air defenses for a longer period, increasing its vulnerability. The B-1B could also fly at a higher weight and accept a reduced ability to maneuver. But this would increase the risk that, being unable to pull up fast enough, the bomber would hit a hill.

A better solution would be to improve the B-1B's flight control system (FCS). The design of the B-1B's basic FCS, which enables the pilot to direct the plane by moving a "stick," determines the maximum angle of attack (AOA) at which the bomber can fly (see Box 1). An improved FCS would enable the bomber to fly at a higher AOA and thus carry more weight. The Air Force is therefore adding two components to improve the B-1B's flight control system: the Stall Inhibitor System and the Stability Enhancement Function.

<u>Stall Inhibitor System</u>. The Stall Inhibitor System (SIS) modifies the B-1B's basic flight control system, which is a hybrid mechanical and "fly-by-wire" system. The mechanical portion of the FCS is similar to the brake system on an automobile: rods connect the pilot's stick to a hydraulic system that in turn moves the flight control surfaces. The fly-by-wire portion, so called because wires carrying electrical signals